PATENT SPECIFICATION

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(19)

(54) ELECTRIC SWITCH

(71) We, FUJITSU LIMITED, a Company organized and existing under the laws of Japan of 1015, Kamikodanaka, Nakahara-ku, Kawasaki-shi, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an electric switch of the type which comprises two sets of rod-shaped fixed contacts formed of a magnetic material and one cylindrical movable contact formed of a permanent magnet. Each set of the fixed contacts are fixed to the respective end of a cylindrical vessel so that the ends of each set of the fixed contacts face the ends of the other set of the fixed contacts with the movable contact capable of reciprocating between the ends of the two sets of fixed electrodes inside the cylindrical vessel.

Hereinafter, such an electric switch is referred to as a flying switch.

The attached Fig. 1 is an illustrative sectional view of the main part of a flying switch. Referring to Fig. 1, two sets of fixed contacts 1,1 and 2,2 are fixed to the respective ends of a cylindrical insulating vessel 4, e.g. a glass tube, so that the ends of each set of the fixed contacts face the ends of the other set of the fixed contacts inside said cylindrical insulating vessel. A movable contact 3 is located between the two sets of fixed contacts 1,1 and 2,2 so as to be capable of reciprocating therebetween. The fixed contacts 1,1 and 2,2 are formed of a soft magnetic material, e.g. 52 Ni- 48 Fe alloy, and the movable contact 3 is formed of a permanent magnet.

In order to actuate the flying switch, each set of fixed contacts 1,1 and 2,2 is magnetized, for example by coils not shown, in the opposite direction to the other set, so as to induce the same magnetic poles (N,N or S,S) at the facing ends of the fixed contacts 1,1 and 2,2. The permanent magnet of the movable contact 3 has its magnetic poles (N, S) on the end planes, each of which faces each set of fixed electrodes. The movable contact 3 is effected at the same time by both attraction and repulsion, and contacts one of the two sets of fixed contacts 1,1 and 2,2. This results in the closing of an electrical circuit of one set of fixed contacts 1,1 or 2,2 thorugh the movable contact 3.

A flying switch does not employ a resilient reed-blade as does the reed contact unit. Further, the flying switch is capable of switching a larger current at higher voltage, even though it is of a smaller size, because the distance between contacts of the flying switch can be larger than that of the reed contact unit and the switching force of the former also can be larger than that of the latter.

The movable contact of a conventional flying switch is composed of a permanent magnet such as a rare earth element-cobalt type magnet coated with a contact layer of metal such as rhodium. However, the permanent magnet is formed by sintering a magnetic powder and is, therefore, difficult to firmly attach to other metals. In addition a sintered magnet, especially a rare earth element-cobalt type magnet, is itself very brittle, although it has an excellent magnetic performance, e.g. high H—B products.

Thus, two very difficult problems are encountered in the conventional flying switch. That is, first, the contact layer of metal is liable to be broken away from the permanent magnet and, second, the permanent magnet is liable to crack or break. These problems lead to reduction in reliability and service life of the flying switch.

It is primary object of the present invention to provide a flying switch in which there is a strong adhesion of the contact layer of metal on the surface of the permanent magnet and with which there is a reduced probability of the contact layer of metal breaking away, and also, of the movable contact itself cracking and breaking.

This object is accomplished by providing an electric switch comprising two sets of rod-shaped fixed contacts formed of a magnetic material and one cylindrical movable contact formed of a permanent magnet, each set of the fixed contacts being fixed to a respective end of a cylindrical vessel so that the ends of each set of the fixed contacts face the ends of the other set of the fixed contacts with the movable contact capable of reciprocating between the ends of the two sets of fixed contacts inside the cylindrical vessel wherein said movable contact comprises at least one adhesive layer of a metal selected from silver, nickel, copper and alloys thereof on the surface of said permanent magnet and at least one contact layer of a metal selected from rhodium, wolfram, rhenium, ruthenium and alloys thereof, silver-wolfram and gold-chromium on said adhesive layer of metal, and at least said permanent magnet and said adhesive layer of metal are thermally diffused to each other.

The switch of the present invention is illustrated in detail with reference to the accompanying drawings, in which:

Fig. 1 is an illustrative sectional view of the main part of a flying switch;

Fig. 2 is a sectional view of the movable contact of the switch according to the present invention;

Fig. 3 is a perspective view of a conventional movable contact of a switch of the prior art, partly broken by the shock of repeated contact operation;

Fig. 4 is a graph showing the relationship between the percent failure and the number of switching times of the switches according to the present invention and those of the prior art;

Fig. 5 is a graph showing the relationship between the force difference (attractive-external impact) and the size ratio (height to diameter) of the movable contact;

Fig. 6 is a graph showing the relationship between the diameter and the size ratio at which the force difference of the movable contact is maximum;

Fig. 7 is a graph showing the relationship between the diameter and the size ratio at which the movable contact cracked or broke;

Fig. 8A is a sectional view of the switch according to the invention, Fig. 8B is an elliptical cross section of the fixed contacts taken along line VIIIB—VIIIB in Fig. 8A;

Fig. 9 is a graph showing the relationship between the breakdown voltage and the distance between two fixed contacts of one pair of fixed electrodes shown in Fig. 8, and;

Fig. 10 is an illustrative sectional view of the switch according to the present invention.

Referring to Fig. 2, because the movable contact 3 of the flying switch has an adhesive layer 6 of metal on the entire surface of the permanent magnet 5 and a contact layer 7 of metal on the entire surface of the adhesive layer 6 of metal, the brittle permanent magnet 5 of the movable contact 3 is protected from the shock of repeated contacts with the fixed contacts. Consequently, the probability of the permanent magnet cracking and breaking is reduced and repeated stable contact of the movable contact 3 with the fixed contacts over a long period of time are possible. The adhesive layer is formed of a metal selected from silver, nickel, copper and alloys thereof, and the contact layer 7 is formed of a metal selected from rhodium, wolfram, rhenium, ruthenium and alloys thereof, silver-wolfram and gold-chromium.

In Fig. 2, both the contact layer and the adhesive layer are single layers. However, a plurality of adhesive layers may be piled on top of each other or a plurality of contact layers and adhesive layers may be arranged alternately.

The combination of the metal of the adhesive layer and that of the contact layer may, preferably, be silver-rhodium, nickel-rhodium, copper-rhodium or silver-wolfram. Of these, an optimum combination is silver-rhodium or nickel-rhodium. Both the adhesive layer 6 of metal and the contact layer 7 of metal can be plated electrochemically. However, they may be attached by means of dry coating such as sputtering.

The diffusion of the metals of the adhesive layer 6 and the permanent magnet 5 can be accomplished by heating after the adhesive layer 6 is formed on the permanent magnet 5 but before the contact layer 7 is formed thereon. Alternatively, the movable contact may be heated, after it is provided with the contact layer 7 on the adhesive layer 6, so as to diffuse both the permanent magnet 5 with the adhesive layer 6 and the adhesive layer 6 with the contact layer 7. This latter method will result in the movable contact 3 being much stronger than with the former method.

As the adhesive layer of metal is formed of silver, nickel or copper, the diffusion can be performed at a temperature in the range of 600 to 750°C. The heat generated by the sputtering of the metallic layers 6 and 7 serves to diffuse the layered metals to a certain extent. Further, the heat generated when the insulating cylindrical vessel 4 (in Fig. 1), e.g. a glass tube, is sealed at 500 to 600°C, promotes metallic diffusion. However, it should be noted that the diffusion temperature of the adhesive layer and the contact layer must not affect the magnetic performance features of the permanent magnet of the movable contact.

The movable contact of the switch of the present invention is, preferably, formed of a rare earth element-cobalt type magnet consisting essentially of (1) one or more rare earth elements such as samarium, cerium and praceodymium, and; (2) cobalt or both

cobalt and iron. The atomic ratio of (1) the rare earth element to (2) the cobalt component is preferably in the range of 1:5 to 1:8.5. The high coercive force of a rare earth element-cobalt type magnet does not deteriorate even at 800 to 900°C, although it is inferior in brittleness to the platinum-cobalt type magnet. However, the latter magnet is high in cost and its coercive force deteriorates at a relatively low temperature such as 300°C. Further, in the rare earth element-cobalt type magnet, a part of the cobalt components may, preferably, be substituted by both copper and vanadium. The amounts of copper and vanadium to be substituted for a part of the cobalt component are preferably 7 to 19% and 0.5 to 6%, respectively, both by weight based on the total weight of (1) the rare earth element and (2) the cobalt component.

Copper, even in the case when its content is low, is effective to improve the fracture resistance of the above-mentioned permanent magnet. However, from the point of view of the coercive force of the permanent magnet, the effective content of copper is limited to the range of 7 to 19% by weight. A vanadium content of less than 0.5% by weight is not effective to prevent the permanent magnet from cracking and a vanadium content of more than 6% by weight reduces its saturation magnetization force.

The rare earth element-cobalt type magnet wherein a part of cobalt component is substituted by both copper and vanadium has an extremely high coercive force, e.g. Hc=4000 Gauss, and a sufficiently high flexural strength, e.g. 18 Kg/mm, to be used as a cast magnet movable contact.

The flying switch provided with a movable contact of the present invention has a long service life, as confirmed in the following experiments.

Movable contact magnets of types A (comparative), B, C_1, C_2, C_3 and D, as shown in the table below, were formed of a rare earth element-cobalt type permanent magnet, consisting of samarium as the rare earth element R and cobalt, iron, copper and vanadium as the transition elements Tr. The atomic ratio of the element R to the elements Tr was 1:7.6. The contents of copper and vanadium were 12% by weight and 1% by weight, respectively, based on the total weight of the permanent magnet. Each permanent magnet body was of a cylindrical shape which had a diameter of 2.6 mm and a height of 2 mm, and thus, the ratio of height to diameter was 0.77. The permanent magnet body was electrochemically plated with a metal, e.g. silver, nickel or copper, to form an adhesive layer, and then, the metal-plated permanent magnet was heated at 750°C for an hour so as to diffuse the adhesive layer of metal and the permanent magnet with each other. Then, the heat-treated body was further electrochemically plated or sputtered with rhodium to form a contact layer on the surface. The metal used for the adhesive layer, the thickness of the adhesive layer and the thickness of the rhodium contact layer were as follows.

Type		Adhesive layer	Contact layer
A	(Comparative)	none	*Rh 10 microns
B		*Cu 10 microns	*Rh 10 ,,
C			
	C_1	*Ni 10 ,,	*Rh 3 ,,
	C_2	*Ni 20 ,,	*Rh 3 ,,
	C_3	*Ni 40 ,,	*Rh 3 ,,
D		*Ag 10 ,,	**Rh 5 ,,

* Electrochemically plated

** Sputtered

Each movable contact magnet was inserted in a glass cylinder of a 4.0 mm inner diameter in an atmosphere of nitrogen, and both ends of the glass cylinder were heat-sealed while two pairs of rod-shoped fixed contacts having a 0.6 mm diameter were fixed to the ends of the glass cylinder at a distance of 1.0 mm. An electric current of 100 volts × 1 ampere was applied to one pair of the fixed contacts and external fields of magnetisation were applied, so as to effect repeated contacts between the movable contact and the fixed

contacts until the switching ceased due to a failure in the switch.

The results of the above life tests are shown in Fig. 4, wherein the term "percent failure" refers to the percentage of the switches in which the contact layer of metal breaks away or the permanent magnet breaks, so that the consequently increased contact resistance between the moving electrode and the fixed electrodes leads to bonding therebetween by fusion or the broken particles inserted between the rod-shaped fixed contacts lead to a short-circuit therebetween. From Fig. 4, it will be understood that the switch of the present invention has more than ten times as long a service life as the switches of the prior art.

Although, in the above experiments, the adhesive layer was formed of silver, nickel or copper and the contact layer was formed of rhodium, similar results are obtained when other metals are used. The suitable metals used for the contact layer include rhodium, wolfram, rhenium, ruthnium and alloys of these elements. Also suitable are alloys such as silver-wolfram and gold-chromium. The suitable metals used for the adhesive layer include silver, nickel, copper and alloys of these elements.

In order to operate the flying switch normally, the permanent magnet of the movable contact must not crack or break during operation. Further the movable contact must not fail to hold contact with the fixed contacts even if an undesirable external impact force F_G is applied to the movable contact in the opposite direction to the attractive force F_a. The attractive force F_a used herein means that with which the movable contact 3 formed of a permanent magnet contacts the fixed contacts 4 formed of a soft magnetic material. The larger the difference between the attractive force F_a and the external impact force F_G, the better the contact between the movable contact and the fixed contact. It now has been found hat, in order to obtain an optimum value of the force difference $F_a—F_G$, the movable contact should be of a cylindrical shape having a certain ratio of length to diameter.

The movable contact of the switch according to the present invention may have the ratio of length T to diameter D, preferably, in the range of 0.3 to 1.0, and, more preferably, in the range of 0.6 to 0.9. Such desired ratios of length T to diameter D of the cylindrical movable contact have been derived from the experiments described below, wherein cylindrical movable contacts of various proportional sizes were prepared and tested for their attractive force F_a and the external impact force F_G was compared to the attractive force Fa.

Each movable contact was formed of a permanent magnet of the same composition as used in the experiments with regard to the life tests illustrated with reference to Fig. 4, however, the movable contacts were provided with neither the adhesive layer of metal nor the contact layer of metal for convenience. The size of the movable contact was varied in the experiments.

One pair of rod-shaped fixed contacts each having a diameter of 1.5 mm were set so that the two fixed contacts were disposed in parallel and separated from each other by a distance of 0.3 mm. Using this pair of fixed contacts and the above-mentioned moving contact, the attractive force F was determined and the external impact force F_G to be applied to the moving electrode was computed as follows.

The attractive force Fa was determined by measuring the force required to remove the contacted movable contact from the fixed contacts by means of a tension tester. The external impact force FG was computed based on the following equation, according to U.S. Military Standard 202 E.

$$FG=m(1+H)g=(1+H)\ \rho\frac{\pi}{4}D^2\ T\ g$$

where

m: mass of moving electrode;
H: external impact value;
g: acceleration of gravity;
ρ: density of moving electrode;
D: diameter of moving electrode;
T: Thickness of moving electrode.

The test results are shown in Fig. 5, wherein lines E and F show the relationship between the force differences Fa—FG and the ratios of length T to diameter D of the cylindrical movable contacts, and in Fig. 6, wherein line E and line F refer to the cases in which H was 50G and 100G, respectively. In the test shown in Fig. 5, the diameter of the movable contact was set at 3.3 mm.

Referring to Fig. 5, the force difference of line E (H=50G) becomes maximum at the ratio of length T to diameter D of 0.91. On the other hand, the force difference of line F (H=100G) becomes maximum at the ratio of length T to diameter D of 0.73.

Referring to Fig. 6, the ratios of length to diameter, at which the force differences are maximum, vary depending upon the diameter as plotted in line E (H=50G) and in line F (H=100G).

The practically acceptable minimum ratio of height to diameter was determined on movable contacts with various ratios of length T to diameter D as follows. Each movable contact was held about 5 mm above a pair of fixed contacts which were arranged upright and not actuated by an exciting force. The movable contact was dropped on the ends of the fixed contacts being propelled

downward by the force of gravity and its magnetic force. The results are shown in Fig. 7, wherein crosses and dots show that the movable contacts were broken before being dropped about one hundred times and not broken when dropped about one hundred times, respectively.

Considering the results shown in Fig. 6 and Fig. 7, the ratio of length T to diameter D should preferably be in the range of 0.3 to 1.0, more preferably, in the range of 0.6 to 0.9.

Each set of fixed contacts of the flying switch of the present invention can be composed of more than two rods formed of a magnetic material. However, each set may, conveniently, comprise a pair of rod-shaped contacts, as shown in Fig. 8A.

Referring to Figs. 8A and 8B, the cross sections of the fixed contacts may, preferably, be shaped as elongated circles, such as ellipses and the like. The pair of contacts 2,2 of elongated circle cross sections is fixed to one end of the cylindrical vessel 4, preferably, in a way such that the major diameter d_1 of each elongated circle is parallel to the other and perpendicular to the imaginary plane involving the two axes of the pair of fixed contacts 2,2. The ratio of the length of the major diameter d_1 to that of the minor diameter d_2 may, preferably, be about 2:1. Such fixed contacts with elongated circle cross sections are capable of supporting the cylindrical movable contacts more stably than the conventional round cross sectioned fixed contacts.

When the cross sectional areas of the fixed contacts 2,2 as described above are the same as those of the conventional round rods and the distance between the axes of the pair of fixed contacts 2,2 is the same, the distance between the two fixed contacts 2,2 in one pair becomes longer than that between the conventional round sectioned fixed contacts. For example, when the distance between two conventional round sectioned fixed contacts in one pair is 0.4 mm, it would be 0.6 mm in the case of the fixed contacts with elongated circle cross sections, provided that the switching capacity is the same. In general, the breakdown voltage obtained between a pair of fixed contacts increases both in d.c. and a.c. with an increase in the distance therebetween as shown in Fig. 9. Therefore, as seen from Fig. 9, the switch provided with such elongated circle cross sectioned fixed contacts disposed at a distance of 0.6 mm exhibits breakdown voltages of about 2,000 V a.c. and about 2,700 V d.c., whereas the conventional switch provided with round sectioned fixed contacts disposed at a distance of 0.4 mm exhibits breakdown voltages of about 1,800 V a.c. and about 2,300 V d.c.

Although the main part of the switch of the present invention is described above, the entire assembly of the switch of the present invention will now be briefly described with reference to Fig. 10, which shows one example of the switch of the present invention. Referring to Fig. 10, a magnetic shunt ring plate 8, formed of a soft magnetic material, is arranged movably in the space around the enclosing glass tube and between excitation coils L_1 and L_2. When the excitation coils L_1 and L_2 are excited in one direction, i.e. the direction shown by arrows in Fig. 10, the magnetic shunt ring plate 8 is located at a certain location by the action of the magnetic force and, then, each of magnetic circuits M_1 and M_2 is closed. On the other hand, when the excitation coils L_1 and L_2 are excited in the opposite direction, the movable contact 3 is brought into contact with the fived contacts 1,1, i.e. not with the fixed contacts 2,2, so that the magnetic shunt ring plate 8 is moved nearer the excitation coil L_2. Although the two closed magnetic circuits M_1 and M_2 temporarily have different boundarys, due to the different locations of the movable contact, it is possible to prevent the two magnetic fluxes from interfering with each other.

WHAT WE CLAIM IS:—

1. An electric switch comprising two sets of rod-shaped fixed contacts formed of a magnetic material and one cylindrical movable contact formed of a permanent magnet, each set of the fixed contacts being fixed to a respective end of a cylindrical vessel so that the ends of each set of the fixed contacts face the ends of the other set of the fixed contacts with the movable contact capable of reciprocating between the ends of the two sets of fixed contacts inside the cylindrical vessel, wherein said movable contact comprises at least one adhesive layer of a metal selected from silver, nickel, copper and alloys thereof on the surface of said permanent magnet, and at least one contact layer of a metal selected from rhodium, wolfram, rhenium, ruthenium and alloys thereof, silver-wolfram and gold-chromium on said adhesive layer of metal, and at least said permanent magnet and said adhesive layer of metal are thermally diffused to each other.

2. An electric switch as claimed in Claim 1, wherein said adhesive layer of metal is formed of silver.

3. An electric switch as claimed in Claim 1, wherein said adhesive layer of metal is formed of nickel.

4. An electric switch as claimed in Claim 1, wherein said adhesive layer of metal is formed of copper.

5. An electric switch as claimed in Claim 1, wherein said adhesive layer of metal is formed of a silver-nckel alloy.

6. An electric switch as claimed in Claim 1, wherein said adhesive layer of metal is

formed of a silver-copper alloy.

7. An electric switch as claimed in Claim 1, wherein said adhesive layer of metal is formed of a nickel-copper alloy.

8. An electric switch as claimed in any one of Claims 1 through 7, wherein said contact layer of metal is formed of rhodium.

9. An electric switch as claimed in any one of Claims 1 through 7, wherein said contact layer of metal is formed of wolfram.

10. An electric switch as claimed in any one of Claims 1 through 7, wherein said contact layer of metal is formed of a silver-wolfram alloy.

11. An electric switch as claimed in any one of Claims 1 to 10, wherein said movable contact is formed of a rare earth element-cobalt type permanent magnet consisting essentially of (1) at least one rare earth element selected from samarium, cerium and praceodymium and (2) cobalt or both cobalt and iron, the atomic ratio of (1) the rare earth element to (2) the cobalt or both cobalt and iron being in the range of 1:5 to 1:8.5.

12. An electric switch as claimed in Claim 11, wherein 0.5 to 6% by weight of vanadium and 7 to 19% by weight of copper, based on the total weight of (1) the rare earth element and (2) the cobalt or both cobalt and iron, are substituted for a part of the cobalt or both cobalt and iron.

13. An electric switch as claimed in Claim 11 or 12, wherein said rare earth element is samarium.

14. An electric switch as claimed in any one of Claims 1 to 13, wherein the ratio of length to diameter of the cylindrical movable contact is in the range of 0.3 to 1.0.

15. An electric switch as claimed in any one of Claims 1 through 14, wherein the cross sections of the fixed contact arranged in pairs are shaped as elongated circles, of which the major diameters are parallel to each other and are perpendicular to the imaginary plane involving the two axes of the fixed contacts in one pair.

16. An electric switch as claimed in any one of Claims 1 to 15, wherein a magnetic shunt ring plate formed of a soft magnetic material is arranged movably in the space around the enclosing cylindrical vessel and between the excitation coils.

17. An electric switch substantially as hereinbefore described with reference to Figs. 2, 8 and 10 of the accompanying drawings.

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Fig. 1

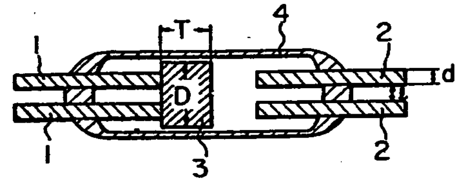


Fig. 2

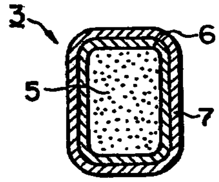


Fig. 3

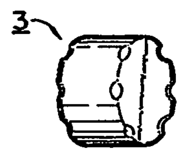


Fig. 5

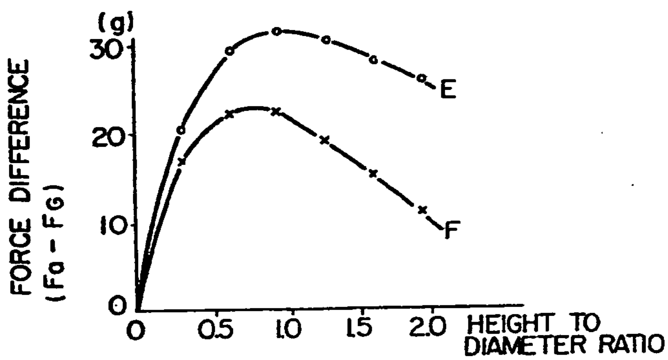


Fig. 4

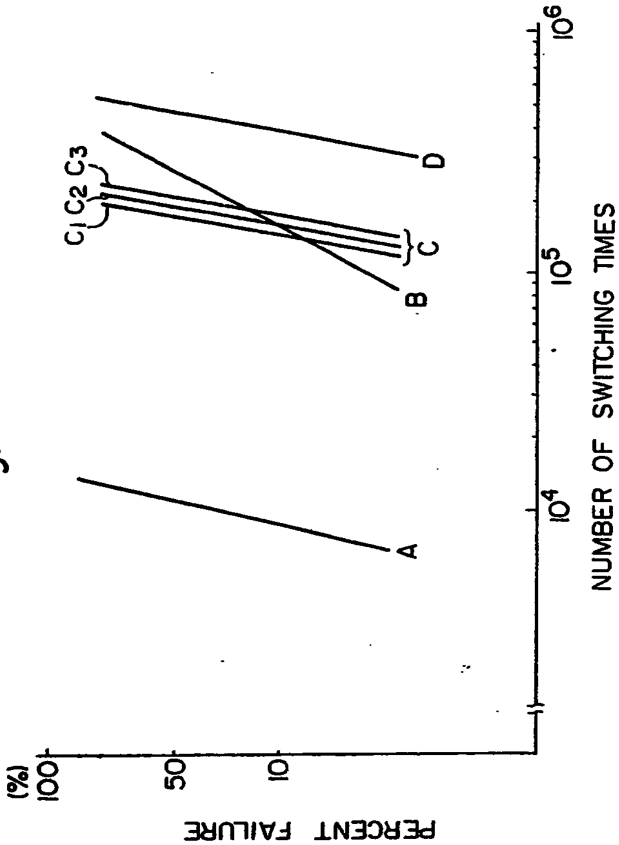

PERCENT FAILURE
(%)
100
50
10
NUMBER OF SWITCHING TIMES
10^4
10^5
10^6
A
B
C
D
C1 C2 C3

Fig. 6

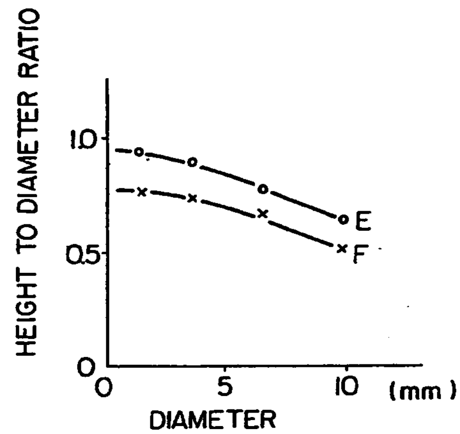
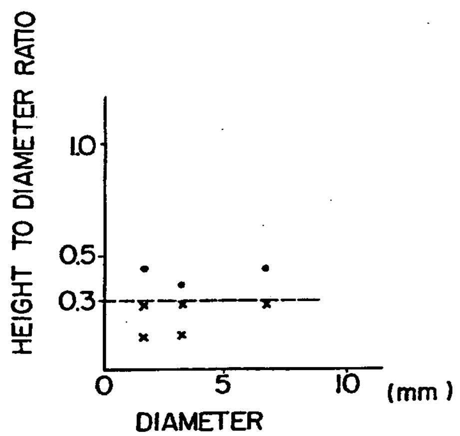

HEIGHT TO DIAMETER RATIO
1.0
0.5
0
E
F
0
5
10
(mm)
DIAMETER

Fig. 7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1.0
0.5
0.3
0
5
10
(mm)
DIAMETER

Fig. 8A

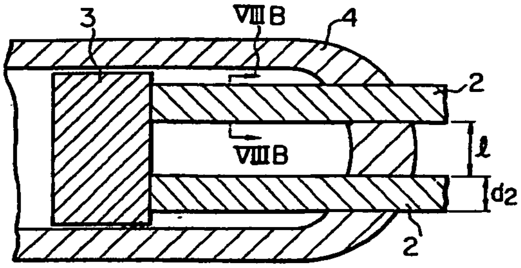

Fig. 8B

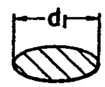

Fig. 9

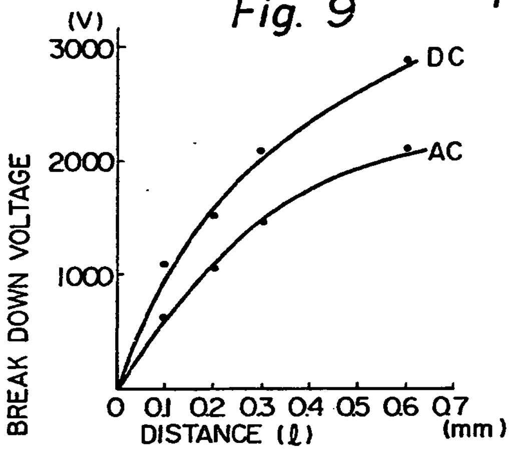

Fig. 10